

Citation:

DiMeglio DP, Mattes RD. Liquid versus solid carbohydrate: effects on food intake and body weight. *Int J Obes Relat Metab Disord*. 2000 Jun;24(6):794-800.

PubMed ID: [10878689](#)

Study Design:

Randomized cross-over clinical trial

Class:

A - [Click here](#) for explanation of classification scheme.

Research Design and Implementation Rating:

POSITIVE: See Research Design and Implementation Criteria Checklist below.

Research Purpose:

This study aimed to document the differential effects of matched liquid and solid carbohydrate loads on diet and body weight.

Inclusion Criteria:

- Classification as an unrestricted eater by scoring ≤ 9 on the Revised Restraint Scale or ≤ 13 on the restraint scale of the Three-Factor eating Questionnaire.
- No self imposed dietary restrictions
- Consumption of ≤ 8 servings of candy and ≤ 8 cans of soda in an average week
- No major illnesses in the past 3 months
- Not taking medications except birth control pills
- Not planning to start a new exercise regime in the next 3 months
- Reporting $\geq 51\%$ control over the selection and preparation of the food they consumed
- Willingness to consume the required amount of jelly beans or soda each day for 4 weeks.
- Data on the timing of menstrual cycle was not available.
- Each participant provided informed consent and the protocol was approved by the Purdue University Committee on the Use of Human Research Subjects.

Exclusion Criteria:

Exclusion criteria was not delineated.

Description of Study Protocol:

Recruitment : Subjects were recruited by public advertisement.

Design: Randomized cross-over clinical trial

Blinding used :

- A cross-over study design was used. To minimize potential bias during dietary reporting, subjects were told that the purpose of the study was to document the effects of sweet loads on stress perception.
- In this double-blind, cross- over study, participants received either real treatment or placebo for a time, and then switched to the opposite treatment

Intervention

- Subjects consumed dietary carbohydrate loads of 1880kJ/day as a liquid (soda) or solid (jelly beans) during two 4 week periods separated by a 4 week washout.
- Diets were alternately selected for sequentially recruited subjects
- Subjects were permitted to consume the loads however they chose.
- Eight of the subjects, four males and four females, were provided with the solid load for 28 consecutive days, followed by a washout period of 28 days, and the liquid load for the final 28 days. The remaining seven subjects, three males and four females, were tested in reverse order.
- To enhance compliance with load consumption, subjects were asked to provide an unstimulated, 3 min saliva sample each week.
- Subjects reported to the testing laboratory each week on the same day and at the same time during the two treatment periods.
- They were instructed not to eat or drink after midnight before their visit.
- They completed the stress questionnaire to maintain the 'study ruse'
- Body weight and composition measurements were taken with subjects in hospital gowns using a TANITA Bodyfat Analyzer, model TBF-105(Tanita Corp. of America Inc., Skokie, IL).
- At the end of the session, subjects were provided with their weekly supply of the appropriate solid or liquid load. They were instructed to consume the stipulated portion each day, but had the freedom to consume it whenever and however they desired
- Subjects were provided with four stress questionnaires to complete at home each week of the four week washout period.

Statistical Analysis

- Statistical analyses were performed with the Statistical Package for Social Sciences (SPSS), version 7.5.2 (Norusis, 1993).
- The level of significance used for all analyses were $P < 0.05$.
- The stress questionnaires and saliva samples were not analyzed.
- All diet records were analyzed by a single individual using the Nutritionist IV nutrient data base, version 4.1(First DataBank, San Bruno, CA
- Repeated measures ANOVA was performed on data (e.g. energy and macronutrient intake, body weight, body composition) obtained at the start and completion of each treatment period (i.e. 4 time points).
- When appropriate, post-hoc comparisons were made with paired t-tests.
- Body weight was available for all 15 participants, however only 14 were analyzed for body composition indices due to a malfunction of the body composition analyzer.
- Hunger data were analyzed four ways.

-Difference values were calculated by subtracting baseline ratings from 180min ratings,

- rebound was calculated by subtracting time zero (immediately after preload consumption) from 180min ratings,
- initial change was calculated by subtracting baseline values from time zero values, and
- the recovery slope was calculated from 0 to 180 min.
- Percentage dietary energy compensation was calculated as $\frac{(((\text{baseline intake} + 1883\text{kJ}) - (\text{free-feeding intake plus } 1883\text{ kJ}))/1883\text{ kJ})}{1883\text{ kJ}} \times 100$.

Data Collection Summary:

Timing of Measurements

- Baseline data were collected over a 1 week period prior to commencing the dietary manipulations
- Subjects consumed dietary carbohydrate loads of 1880kJ/day as a liquid (soda) or solid (jelly beans) during two 4 week periods separated by a 4 week washout.
- In addition to baseline measurements, diet records were obtained on random days throughout the study, body composition was measured weekly, physical activity was assessed before and after treatments and hunger was assessed during washout and midway through each treatment.
- To enhance compliance with load consumption, subjects were asked to provide an unstimulated, 3 min saliva sample each week.
- Subjects reported to the testing laboratory each week on the same day and at the same time during the two treatment periods.
- They completed the stress questionnaire to maintain the 'study ruse'
- Body weight and composition measurements were taken with subjects in hospital gowns using a TANITA Bodyfat Analyzer, model TBF-105(Tanita Corp. of America Inc., Skokie, IL).
- Subjects were provided with four stress questionnaires to complete at home each week of the four week washout period.

Dependent Variables

- Body weight and composition measurements were taken with subjects in hospital gowns using a TANITA Bodyfat Analyzer, model TBF-105(Tanita Corp. of America Inc., Skokie, IL).
- Energy and Micronutrient Intake-All diet records were analyzed by a single individual using the Nutritionist IV nutrient data base, version 4.1(First DataBank, San Bruno, CA)
 - Dietary assessments
 - Twenty-four hour diet recalls were obtained from subjects over the telephone
 - They were called on random days and asked to report all foods and beverages consumed during the previous day
 - Recalls were conducted three times during baseline and six times during treatments and washout.

- Recalls were only conducted if subjects indicated the prior day was not markedly atypical.
- Subjects also self-reported the manner in which the loads were consumed, either as a meal, with a meal or as snack.
- **Hunger ratings**
 - Hunger questionnaires were completed by subjects after an overnight fast at the end of the third weekly meeting of each load period and twice during the washout period.
 - Self-reported hunger and fullness ratings were obtained on a 13-month scale where 1=not at all and 13=extremely.
 - Subjects then consumed one of four preloads : (1)941.4kJ (225 kcal) of jelly beans; (2) 941.4kJ (225kcal) of soda; (3) 129.48 g Vlasic Dill Spears (Camden, New Jersey); or (4) deionized water (matched in volume to soda) in 20 min.
 - The pickles and water were used as weight and volume controls for the jelly beans and soda, respectively.
 - Immediately after preload consumption, hunger and fullness were re-rated.
 - Subjects were then allowed to leave the testing laboratory but continued ratings at 15, 30, 60, 90,120,150; and 180 min.
 - Subjects were instructed not to eat or drink anything until after completion of the 180 min period.

Independent Variables

- **Experimental Foods:**
 - The solid load was comprised an 1883 kJ(450kcal) servings of jelly beans(Blueberry, Bubble Gum, Champagne Punch, Cherry, Grape, Green Apple, Island Punch, Lemon, Orange, Sherbet, Raspberry, Strawberry Daiquiri and Tangerine, Jelly Belly-National Bulk Food Distributors, Inc, Taylor, Michigan).
 - The energy density of the jelly beans was 16.7 kJ/g (4 kcal/g)
- The liquid load was an 1883kJ(450kcal) serving of caffeine-free soda (A&W Root Beer, Dallas, TX; Coca-Cola, Atlanta, GA, Faygo Crème, Grape, Orange and red Pop, Detroit, MI; Pepsi, Somers, NY; and Sprite, Atlanta, GA).
 - The energy densities of the sodas ranged from 165kJ/ml (0.39 kcal /kJ/ml) to 2.30kJ/ml (0.55 kcal/ml).
 - Because of the differences in the energy content of the sodas and flavor preferences, slight variations were made in quantities provided so energy content was fixed.
- Nearly all of the energy from the sodas and jelly beans was in the form of carbohydrate.

Control Variables

- Age
- Sex
- Physical activity was assessed by each participant at the beginning and end of each treatment period using thr the Seven-Day Physical Activity Recall questionnaire.

Description of Actual Data Sample:

Initial N: 7 males and 8 females

Attrition (final N): 7 males and 8 females

Age: mean(s.d) age 22.8 ± 2.73 y

Ethnicity: not specified

Other relevant demographics: none specified

Anthropometrics: Baseline : mean(s.d.) BMI: 21.9 ± 2.2 kg/m²

Location: Indiana, USA

Summary of Results:

Key Finding: Tables 1

Free-feeding energy intake during the solid period was significantly lower than intake prior to this period.

- Dietary energy compensation for the solid load was 118% (95% CI: (0.88 - 1.48).
- All subjects had lower free-feeding energy intakes during the solid load ($P < 0.001$).
- No decrease in free-feeding energy intake occurred during the liquid period.
- Total daily energy intake increased by an amount equal to the load resulting in dietary compensation of -17% (95% CI: -0.60-0.26), indicating subjects actually ate more of their customary diet.
- Consequently, body weight and BMI increased significantly only during the liquid period, although the change in body weight between the two conditions was not significant.
- Physical activity and hunger were unchanged.

Table 1 Mean (s.d.) body weight and composition values ^a

	Body weight kg(lb)	Body mass index ^a
Pre-solid	68.0 ± 5.0 (149.5 ± 33.10)	22.1 ± 2.3
Post-solid	68.3 ± 14.9 (150.3 ± 32.80)	22.2 ± 2.2
Pre-liquid	67.7 ± 14.7 (149.0 ± 32.3)	21.8 ± 2.2
Post-liquid	68.2 ± 14.5 (150.1 ± 31.7) ^b	21.9 ± 2.1 ^b

^a All analyses were performed with an n of 15 except for BMI during supplementation (n=14).

^b End of liquid supplementation significantly different from pre-treatment values, $P \leq 0.05$.

Author Conclusion:

This study indicated that liquid carbohydrate promoted positive energy balance, where as a

comparable solid carbohydrate elicited precise dietary compensation. Increased consumption of energy-yielding fluids may promote positive energy balance.

Reviewer Comments:

Limitations:

- One methodological aspect of this study that could bear on the outcome is the fact that the forms of carbohydrate were not perfectly matched. The beverages contained high fructose corn syrup as the predominant sweetener, whereas the jelly beans were high in sucrose. Based on the glucostatic theory of hunger, the higher fructose-containing load (soda) should be more satiating. The researchers noted that no differences in subjective appetitive responses were observed and dietary responses were contrary to this expectation.
- A second methodological issue concerns the use of 24h food recalls to document dietary intake. While this is clearly an imperfect measure, it did not appear to pose a threat to the interpretation of the present data. First, because this was a within-subject design, individual reporting biases and inaccuracies would likely have held equally during both treatment arms. Secondly, subjects were unaware of the true purpose of the study so could not anticipate the expected outcome. Finally, the lack of sensitivity of recalls would be expected to mask treatment effects rather than produce them.

Research Design and Implementation Criteria Checklist: Primary Research

Relevance Questions

- | | | |
|----|---|-----|
| 1. | Would implementing the studied intervention or procedure (if found successful) result in improved outcomes for the patients/clients/population group? (Not Applicable for some epidemiological studies) | Yes |
| 2. | Did the authors study an outcome (dependent variable) or topic that the patients/clients/population group would care about? | Yes |
| 3. | Is the focus of the intervention or procedure (independent variable) or topic of study a common issue of concern to nutrition or dietetics practice? | Yes |
| 4. | Is the intervention or procedure feasible? (NA for some epidemiological studies) | Yes |

Validity Questions

- | | | |
|------|---|-----|
| 1. | Was the research question clearly stated? | Yes |
| 1.1. | Was (were) the specific intervention(s) or procedure(s) [independent variable(s)] identified? | Yes |
| 1.2. | Was (were) the outcome(s) [dependent variable(s)] clearly indicated? | Yes |

1.3.	Were the target population and setting specified?	Yes
2.	Was the selection of study subjects/patients free from bias?	Yes
2.1.	Were inclusion/exclusion criteria specified (e.g., risk, point in disease progression, diagnostic or prognosis criteria), and with sufficient detail and without omitting criteria critical to the study?	Yes
2.2.	Were criteria applied equally to all study groups?	Yes
2.3.	Were health, demographics, and other characteristics of subjects described?	Yes
2.4.	Were the subjects/patients a representative sample of the relevant population?	Yes
3.	Were study groups comparable?	Yes
3.1.	Was the method of assigning subjects/patients to groups described and unbiased? (Method of randomization identified if RCT)	Yes
3.2.	Were distribution of disease status, prognostic factors, and other factors (e.g., demographics) similar across study groups at baseline?	Yes
3.3.	Were concurrent controls used? (Concurrent preferred over historical controls.)	Yes
3.4.	If cohort study or cross-sectional study, were groups comparable on important confounding factors and/or were preexisting differences accounted for by using appropriate adjustments in statistical analysis?	N/A
3.5.	If case control or cross-sectional study, were potential confounding factors comparable for cases and controls? (If case series or trial with subjects serving as own control, this criterion is not applicable. Criterion may not be applicable in some cross-sectional studies.)	N/A
3.6.	If diagnostic test, was there an independent blind comparison with an appropriate reference standard (e.g., "gold standard")?	N/A
4.	Was method of handling withdrawals described?	N/A
4.1.	Were follow-up methods described and the same for all groups?	N/A
4.2.	Was the number, characteristics of withdrawals (i.e., dropouts, lost to follow up, attrition rate) and/or response rate (cross-sectional studies) described for each group? (Follow up goal for a strong study is 80%.)	N/A
4.3.	Were all enrolled subjects/patients (in the original sample) accounted for?	Yes
4.4.	Were reasons for withdrawals similar across groups?	N/A
4.5.	If diagnostic test, was decision to perform reference test not dependent on results of test under study?	N/A

5.	Was blinding used to prevent introduction of bias?	Yes
5.1.	In intervention study, were subjects, clinicians/practitioners, and investigators blinded to treatment group, as appropriate?	Yes
5.2.	Were data collectors blinded for outcomes assessment? (If outcome is measured using an objective test, such as a lab value, this criterion is assumed to be met.)	N/A
5.3.	In cohort study or cross-sectional study, were measurements of outcomes and risk factors blinded?	N/A
5.4.	In case control study, was case definition explicit and case ascertainment not influenced by exposure status?	N/A
5.5.	In diagnostic study, were test results blinded to patient history and other test results?	N/A
6.	Were intervention/therapeutic regimens/exposure factor or procedure and any comparison(s) described in detail? Were intervening factors described?	Yes
6.1.	In RCT or other intervention trial, were protocols described for all regimens studied?	Yes
6.2.	In observational study, were interventions, study settings, and clinicians/provider described?	N/A
6.3.	Was the intensity and duration of the intervention or exposure factor sufficient to produce a meaningful effect?	N/A
6.4.	Was the amount of exposure and, if relevant, subject/patient compliance measured?	Yes
6.5.	Were co-interventions (e.g., ancillary treatments, other therapies) described?	N/A
6.6.	Were extra or unplanned treatments described?	N/A
6.7.	Was the information for 6.4, 6.5, and 6.6 assessed the same way for all groups?	Yes
6.8.	In diagnostic study, were details of test administration and replication sufficient?	N/A
7.	Were outcomes clearly defined and the measurements valid and reliable?	Yes
7.1.	Were primary and secondary endpoints described and relevant to the question?	Yes
7.2.	Were nutrition measures appropriate to question and outcomes of concern?	Yes
7.3.	Was the period of follow-up long enough for important outcome(s) to occur?	Yes
7.4.	Were the observations and measurements based on standard, valid, and reliable data collection instruments/tests/procedures?	Yes
7.5.	Was the measurement of effect at an appropriate level of precision?	Yes

7.6.	Were other factors accounted for (measured) that could affect outcomes?	Yes
7.7.	Were the measurements conducted consistently across groups?	Yes
8.	Was the statistical analysis appropriate for the study design and type of outcome indicators?	Yes
8.1.	Were statistical analyses adequately described and the results reported appropriately?	Yes
8.2.	Were correct statistical tests used and assumptions of test not violated?	Yes
8.3.	Were statistics reported with levels of significance and/or confidence intervals?	Yes
8.4.	Was "intent to treat" analysis of outcomes done (and as appropriate, was there an analysis of outcomes for those maximally exposed or a dose-response analysis)?	N/A
8.5.	Were adequate adjustments made for effects of confounding factors that might have affected the outcomes (e.g., multivariate analyses)?	N/A
8.6.	Was clinical significance as well as statistical significance reported?	Yes
8.7.	If negative findings, was a power calculation reported to address type 2 error?	N/A
9.	Are conclusions supported by results with biases and limitations taken into consideration?	Yes
9.1.	Is there a discussion of findings?	Yes
9.2.	Are biases and study limitations identified and discussed?	Yes
10.	Is bias due to study's funding or sponsorship unlikely?	Yes
10.1.	Were sources of funding and investigators' affiliations described?	Yes
10.2.	Was the study free from apparent conflict of interest?	Yes

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